Apollo's 50th Anniversary
Frank Slomka, Ulm University
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Teaching Embedded System Design with Simscape and Simulink
Computer Simulations
Computer Simulations

Source: Nasa
Computer Simulations

Source: Nasa
How to teach engineering?
Build something!

Embedded Systems?

Source: Tyne and Wear Archives & Museums @ flickr.com
Moon landing
1. Try: Simscape
Lunar lander

Guidance

Gravity

Moon

Input
What about fuel?
Moon landing
2. Try: Simulink
Fly me to the moon - Then an now

Richard J. Gran  30 years anniversary

1 h to model!

Source: Mathworks
But:

That same year, I became a member of the Grumman Guidance and Control group and, as such, participated on field assignment, in the design of the Lunar Module digital autopilot at MIT Instrumentation Laboratories from 1963 to 1966.

Richard J. Gran
How to solve complex technical problems....

....if I know nothing!

Source: Pannel_2010, Flickr
Modeling
Build a model is one thing…

…but how to land?

Source: NASA
Astronauts fail on landing by hand

A NASA team of 10 people did simulations 2 years!

...but how to land?
**LM Powered Descent**

<table>
<thead>
<tr>
<th>Engine Ignition</th>
<th>Maximum Throttle</th>
<th>Target Switchover</th>
<th>LR Altitude Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>h=50,000 FT</td>
<td>h=50,000 FT</td>
<td>h=43,000 FT</td>
<td>h=25,000 FT</td>
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<tr>
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<td>$\theta=88^\circ$</td>
<td>$\theta=80^\circ$</td>
<td>$\theta=71^\circ$</td>
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<tr>
<td>T=0 SEC</td>
<td>T=28 SEC</td>
<td>T=228 SEC</td>
<td>T=328 SEC</td>
</tr>
<tr>
<td>V=5500 FT/SEC</td>
<td>V=5564 FT/SEC</td>
<td>V=3385</td>
<td>V=2164 FT/SEC</td>
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<td>$\gamma=-.2^\circ$</td>
<td>$\gamma=-1.4^\circ$</td>
<td>$\gamma=-4.0^\circ$</td>
</tr>
</tbody>
</table>

...but how to land?

Source: NASA
…but how to land?
GUIDANCE COMMANDS FOR POWERED DESCENT

...but how to land?

Source: Nasa
That way!
The result:
Schubsteuerung

Vorberechnungen für die Steuerung (anhand der vorgegebenen Sollgeschwindigkeiten)

Rotationssteuerung

Winkelgeschwindigkeit

Winkel
The result

- Simscape: 2 students
- Simulink model: 1 student
- **Landing: 2 students**

v_rad_soll, v_rad_ist, v_tan_soll, v_tan_ist
They want 'Delta-H', which compares the radar's and computer's value for height.
102:38:21 Armstrong: Sure do. Houston, (I hope) you're looking at our Delta-H.


102:38:26 Armstrong: (With the slightest touch of urgency) Program Alarm.


102:38:30 Armstrong: (To Houston) It's a 1202.

102:38:32 Aldrin: 1202. (Pause)


102:38:53 Duke: Roger. We got you...(With some urgency in his voice) We're Go on that alarm.
Program Delta H

- Alt = 50,000 ft
  - Vel = 5548 fps
  - R_{GO} = 240 nm

- START LR Alt UPDATING
  - Alt = 39,200 ft
  - Vel = 3,065 fps
  - Time = 4 min: 18 sec

- START LR VELOCITY UPDATING
  - Alt = 22,645 ft
  - Vel = 1315 fps
  - Time = 6 min: 42 sec

- HIGH-GATE POINT
  - Alt = 7400 ft
  - Vel = 434 fps
  - R_{GO} = 4.5 nm

- LOW-GATE POINT
  - Alt = 500 ft
  - Vel = 70 fps
  - R_{GO} = 0.3 nm

- BRAKING PHASE
  - (8 min: 26 sec)

- APPROACH OR VISIBILITY PHASE
  - (1 min: 40 sec)

- TERMINAL LANDING PHASE
  - (1 min: 30 sec)
Echtzeitsysteme?
Echtzeitsysteme?
How a Small Real-Time Bug Endangered the Apollo 11 Mission

1. The Apollo 11 Mission

The NASA had in the 1960’s and 70’s a program named “Apollo” to bring men into space and onto the moon. The Apollo 11 Mission was the first to finally land on the moon. On July 20th 1969 at 20:17:58 UTC the first man made space vehicle landed and returned safely to earth with three astronauts on board.

During the approach with the LEM (Lunar Excursion Module) named “Eagle” the calculation of the correct flight path and control of the propulsion system was performed by the LGC (Lunar Guidance Computer). Mid way of approaching the moon the system reported two errors (#1201 and #1202) due to a timing problem in the LGC’s program. This demo shall simulate the processes on the LGC and show how it came to the real-time errors. This is for demo purposes only and is based on the publicly available data published by NASA and others.

Source: Apollo 11 Press Kit - 06/26/69 - For the Apollo Lunar Surface Journal
Paper Capture by Ronald A. Wells - Restored version by Luigi Morelli
Original Bitmap Source Scans: KSC Library